Estimation of Vertical Distributions of Water Vapor and Aerosols from Spaceborne Observations of Scattered Sunlight

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LONG-TERM GOALS

The scientific aims of this project are to investigate, develop and apply methods based solidly on scattering physics and inverse theory to estimate vertical distributions of water vapor and aerosol properties from hyperspectral observations of scattered sunlight. We seek especially to advance methods for the lower troposphere, where water vapor and aerosols are concentrated and affect naval systems strongly. We are presently working on a method applicable over the sea surface.

OBJECTIVES

The current focus of the project is on physics and inverse theory for retrieval of water vapor profiles very near sea and littoral land surfaces (from roughly 0 - 500 mB) using high spectral resolution near-IR observations of scattered sunlight, such as are expected from the NEMO/COIS sensor. We are working to quantify the fidelity and altitude ranges of inversion based on clear-air aerosol scattering, and to test alternative methods for this inversion using existing (airborne) hyperspectral observations, to the degree possible.

APPROACH

In the approximation of first-order aerosol scattering, the problem can be cast as a linear inverse problem formally similar to that of temperature sounding using microwave radiation near the oxygen absorption complex. Methods used to analyze the information content of various prospective temperature-sounding observations therefore can also be applied in this case. In particular, we use singular-value-decomposition to understand the number of profile parameters parameters for which representative (prospective) data set can inverted. We also use Backus-Gilbert theory to understand the altitude range over which inversion is informative, as a function of the aerosol distribution with altitude. We seek to quantify the 'quality' of aerosol distribution knowledge necessary to result in water vapor profiles of useful accuracy. We are also seeking existing AVIRIS data sets that can be used to test theoretical methods observationally.

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WORK COMPLETED

Our investigations have shown that the combination of viewing from the top of the atmosphere, relatively high terrestrial tempeatures, and (from a spectroscopist's point of view) modest spectral resolution of 10 nm seriously limits water vapor profiling using sunlight scattered to the sensor by underlying land surfaces. The success in profiling atmospheric trace gases using similar methods in planetary science [see, e.g., Coustenis et al., 1991] results largely from the much higher spectral resolution available with sensors on interplanetary probes and ground-based telescopes. Thus, even though the relatively high temperatures on Earth constitute an additional challenge, trace gas profiling over land should be revisited if the spectral resolution of future Earth-observing sensors is further improved. We reported on this work at the 1999 Fall Meeting of the American Geophysical Union [Winebrenner and Sylvester, 1999].

We have, however, also pursued a promising method for water-vapor profiling over ocean surfaces. This method is based on hyperspectral observation of sunlight scattered by aerosols at wavelengths near water vapor absorption features, though it must presume 'adequate', indepedent knowledge of the vertical distribution of aerosol scattering properties. (We expect such information in practice to be acquired from some combination of air mass modeling and lidar data.) We have completed the formulation of the inverse problem based on radiative transfer theory, specializing for now to the case of clear-air scattering with small optical depths (i.e., a first-order scattering assumption) and nadir observation angle. We have begun to characterize the information content and range of accurate inversion possible using various combinations of near-infrared water vapor absorption features.

RESULTS

Two issues of first-order importance are (1) the theoretically feasible vertical resolution of retrieved water vapor profiles (which is closely coupled to the retrieval information content), for different (assumed) aerosol distributions with altitude; and (2) the relationships between uncertainties in aerosol distributions and resulting uncertainties in water vapor profile retrievals. Because some near-IR water vapor absorption features are quite sharp-edged (as functions of wavelength), uniform aerosol distributions (in altitude) can theoretically provide finely resolved water vapor profiles. More realistic aerosol altitude distributions in the sea surface boundary layer are concentrated near the surface with scale heights roughly comparable to water vapor scale heights. Resolution in such cases depends on altitude. The availability of several absorption features of differing depths improves the altitude range of accurate profile retrieval considerably. Insightful quantification of the coupling between quality of (realistic) aerosol profile information and quality of water vapor profile inversion is presently the foremost research issue.

IMPACT/APPLICATIONS

Advances in this work impact several fields in addition to that of naval sensor performance modeling: linear inversion theory (via advances in mathematics and methods), air-sea interaction (by providing new probing methods and information for near-surface fluxes), and boundary-layer meteorology (by improving understanding of lower boundary conditions and radiative and latent heat fluxes).

TRANSITIONS

Transitions from this work to related efforts have not yet been made.

RELATED PROJECTS

Water vapor estimation methods developed in this work may be adapted to related problems (possibly including other trace gases) in other geophysical settings.

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PUBLICATIONS

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